Solar Powered AUVs; Sampling Systems for the 21st Century

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LONG TERM GOALS

The long-term goal of this program is to investigate those technologies that will enable the use of solar energy to power Autonomous Underwater Vehicles (AUVs). The program will focus on investigation of our ability to extract sufficient energy from the sun's radiation to power an AUV and our ability to efficiently manage the collection, storage, and utilization of that energy such that an AUV is able to perform tasks required during a mission. It is expected that, at the conclusion of this phase of the program, we will understand not only the relevant technologies, but also the advantages, methods of implementation, and limitations of their use on solar AUVs (SAUV).

OBJECTIVES

Maximize the potential mission length of SAUVs by optimization of the energy extraction from PV Solar panels using low power consumption electronics and intelligent battery charging techniques. Characterize and optimize SAUV hull design with respect to reducing drag resistance, improving stability, and maximizing propulsion efficiency. Integrate GPS navigation and RF communications systems into the SAUV and link these systems to an interactive AUV computer simulation environment currently under development at AUSI.

APPROACH

Conduct research on existing solar energy components, their usefulness and potential for application in an integrated system for AUVs. Conduct experiments to acquire data and assess the extent to which solar energy is viable as a power source for AUVs. This involves designing a solar energy system testbed to conduct laboratory experiments to specifically determine the efficiencies and limitations of subsystems composed of PV solar arrays, battery systems, charge monitors and charge controllers, etc., and to assess the degree of integration compatibility between the various electronic components. Use the solar energy testbed to investigate various power management strategies developed within this program. Design and fabricate a solar AUV platform for the purpose of carrying out in-water evaluations of energy collection under conditions of wave motion and water splashing over solar arrays. Develop software models of waves, platform, and energy system to serve as an evaluation and design tool and to conduct simulation experiments of various aspects of solar AUV systems. Design and fabricate a simple solar AUV prototype vehicle to conduct at sea tests of the first principles of solar powered AUVs.

Planned Research and Science and Technology Efforts

The overall research effort is to develop an understanding of the technologies required to produce an SAUV for long-term deployment in oceanographic research. Planned science and technology efforts include:

- In depth investigation of the use of GPS navigation and RF communications, as well as the characterization of the real life energy usage of these systems.
- Continued optimization of hull design, drag profile, and propulsion efficiency.
- Power management development including the benefits of the maximum power point tracking electronics.

Clearly, maximizing the duration of an SAUV mission is the measure of success in the development of these vehicles. The experimental results of the completed research have increased our understanding of the fundamental technologies involved in producing a feasible, working SAUV, as well as our understanding of the limitations of these technologies.

WORK COMPLETED

At Sea Performance Testing of Prototype Solar AUV

1. Fabrication of complete solar powered AUV with remote communications and GPS positioning subsystems.
2. Functional check, debugging and operational development of the vehicle devices and systems.
3. Estimation of the hydrodynamic characteristics and comparison with calculated models including: motion control in vertical and horizontal plane, propulsion efficiencies, and free and controllable ascent.
4. Estimation of vehicle behavior at rough sea during running and drifting; particularly flooding of the upper surface of the vehicle and the effect on operation of the solar cells, GPS and communications systems.

Solar Energy System Test Bed

1. Development and optimization of microprocessor controlled battery-charging algorithm.
2. Characterization of battery-charging profile using distinct panels alternately charging and operating various electronic loads.
3. Comparison of battery charging with DC to DC converter vs. direct connection to solar panel.
4. Initial design and implementation of Maximum Power Point Tracking (MPPT) electronics for most efficient use of solar panel energy during battery charging.

RESULTS

At Sea Performance Testing of Prototype Solar AUV

With the current SAUV hull shape, experiments on motion performance with varying drag resistance and propulsion systems were conducted. It has been determined that a motor with a range of efficiency of 10 to 20W is optimum at the rotational frequency of 400 to 600 RPM [4]. The optimal operating velocity should be 0.6 to 0.8 m/s. Vehicle controllability decreases at lower velocities and long cruising range decreases significantly at higher velocities. Also it was seen that in a free ascent, without the aid of thruster propulsion, the vehicle will not assume an adequate attack angle and will have unpredictable lateral movement. Free and controllable ascent can be accomplished with a change in hull design, which would allow the shift of the hydrodynamic force from the center of buoyancy to the stern, thereby ensuring the proper pitch moment. Another possibility that will be examined is a gravity force displacement along the longitudinal axis. This could be accomplished by sliding the storage battery inside the pressure housing using a servo motor system to change the pitch moment. The prototype SAUV was found to have absolute stability during at-sea testing – the vehicle reverts to its upright position following overturn in rough sea. Accumulation of water on the deck of the SAUV was found to not strongly effect the energy reception of the solar panels. Additionally, the flooding of the solar panels provided cooling to the panels, partially compensating for any decrease in energy output. Preliminary at-sea testing of the GPS navigation system showed an operational system, which would accurately update position information every 40 to 70 seconds in calm seas and every 150 to 190 seconds in class 2-3 seas. The battery-charging system employed a first generation MPPT charger, which has been characterized for performance on shore. At sea testing of the MPPT system is ongoing.

Solar Energy System Test Bed

A complete, functional solar energy battery charger/power conversion system has been constructed and tested [5]. The system is comprised of two Solarex MSX30L solar arrays, a gas gauge and charge controller (Benchmarq bq2112), and three Sanyo KR-10000M NiCad battery packs. Each pack contains 8 Nickel Cadium cells in series. Currently a microprocessor controlled battery-charging algorithm is in use and the battery charge/discharge profiles are being recorded and analyzed for optimum efficiency. The microprocessor is given information about the state of charge of each battery pack from the bq2112, and determines in which mode, charge or run, each pack should be. Recent improvements to the algorithm include the addition of an error checking routine. Occasionally, incorrect or corrupted information concerning the status of the batteries is sent to the microprocessor from the bq2112 gas gauge circuit. The error checking software routine makes several reads of the data and compares the information. Any incorrect bits of data are easily seen and the correct information is extracted. There are three solar panels in the system, allowing for direct comparisons between differing charging algorithm and power management techniques. In one test a DC to DC converter (without maximum power point tracking or MPPT) was used to charge a battery and the results were compared with the charging of the battery directly from the solar panel. It was determined to be less efficient to use the DC to DC converter. A DC to DC converter using a synchronous buck regulator topology in an MPPT configuration has been designed and will be implemented in a similar test to determine its effect on the overall efficiency of the system.

IMPACT/ APPLICATIONS

The use of solar powered AUVs in the future will allow scientists and military investigators to perform missions of the sort, which are unattainable at present. Solar AUVs will allow users to remotely conduct missions in which they can acquire significant data over vast areas of the ocean for long periods of time, and have access to the data and vehicle through communication on a daily basis. This is a significant first step in providing at sea satellites.

TRANSITIONS

This technology should undergo a series of long endurance at sea trials in conjunction with scientists and/or military users to assist in the transition from technology development and assessment to commercial viability.

RELATED PROJECTS

This work has direct relevance to the Autonomous Ocean Sampling Network (AOSN) project since solar powered AUVs could well serve as autonomous agents within that network. Similarly, the work on Cooperative Distributed Problem Solving for controlling AOSNs (ONR #N00014-96-1-5009), which is also being accomplished at AUSI, also is relevant for this solar powered AUV system.

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